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ABSTRACT

The unidentified high latitude UHURU sources are shown to be consistent with an interpretation which does not require most of them to be extragalactic.

It has been suggested (Matilsky, et al. 1973) that all of the weak, isotropically distributed, unidentified sources catalogued by UHURU (Giacconi, et al. 1972) are extragalactic. This hypothesis is exceedingly important as regards the origin of the "diffuse" x-ray sky background, as the dominant contribution to this "diffuse" flux may well arise from such extragalactic sources if this identification is correct. The purpose of this communication is to point out the premature (and very possibly fallacious) nature of this identification, as the data in hand appear to us to be reconcilable with discrete sources within our own galaxy.

The evidence considered by Matilsky, et al. in reaching the conclusion that the sources are extragalactic is as follows:

1. The log N-log S plots for sources for which $|b| > 20°$ and for which $|b| < 20°$ are markedly different.

2. The 33 UHURU sources considered with $|b| > 20°$ are distributed isotropically.

3. The slope of the log N-log S plot for the $|b| > 20°$ sources is consistent with what would be expected from the nearby (i.e. non-evolutionary) metagalaxy.

4. There exist seven firm identifications with unusual extragalactic objects in the $|b| > 20°$ sample, and several more tentative associations.

5. A local source model is apparently (our italics) inconsistent with the existing data.

There exist data not considered by Matilsky, *et al.* which make the present exercise more than a critique of the soundness of their logic. In particular, Bleach, *et al.*(1972) have reported evidence for a narrow ridge of unresolvable galactic x-ray emission in the interarm region of the plane near ℓ=60°. Such emission is most easily reconcilable with a population of low luminosity ($\lesssim 10^{33}$ erg/sec) x-ray emitters confined to within a few hundred parsecs of the galactic plane. It was suggested in that paper that many of the weak high latitude UHURU sources could belong to this new population, and the availability of the Matilsky, *et al.* analysis now allows us to explore this possibility in detail without danger of misinterpretation of the UHURU data.

Addressing ourselves to the cited arguments for an extragalactic identification in the order listed above, the implication from log N-log S plots of a source population quite separate from the "ordinary" galactic sources with luminosity $\gtrsim 10^{36}$ erg/sec is consistent with either explanation. This is also true of the second and third points, which imply that the source distribution is both isotropic and uniform. A log N-log S slope of -1.5 is expected for a completely uniform distribution of identical emitters in a Euclidean space, while Matilsky, *et al.* report -1.34 $\pm$ 0.2 for the high latitude UHURU sources. If local, and if the scale height of the distribution is approximately equivalent to the UHURU sensitivity, we should expect the log N-log S slope to be slightly harder than -1.5 without a significant departure from isotropy at the level of the counting statistics available. It is also worth noting that the high latitude sources do, in fact, exhibit a clustering toward lower latitudes (Kellogg 1972), but we do not consider either the flattened slope or the low latitude clustering particularly strong points in favor of local sources when considered independent of other evidence, in view of the effects which non-identical source luminosities can create in a restricted sample of data, they certainly cannot strengthen the extragalactic case, however.

Matilsky, *et al.* correctly point out that 7 of the 33 $|b| > 20°$ sources considered have been positively identified with extragalactic objects, with a like number of tentative identifications, but we have serious reservations about using this fact to support the general extragalactic hypothesis. The majority of the high latitude sources already found, and the preponderance of those below the Matilsky, *et al.* threshold of 3 UHURU counts/sec which are expected, are not identifyable. This has necessitated the postulation of ultra-luminous "x-ray galaxies" (Giacconi, *et al.* 1971) to account for these sources, so that the existing identifications cannot be used as evidence for a general extragalactic hypothesis if a new class of super x-ray emitters is required for the great majority. Using the Matilsky, *et al.* fractional coverage prescription, the 33 observed sources are a sample from ~100 which complete sky coverage at a UHURU senstivity of 3 cts/sec could uncover, and ~500 at the ultimate UHURU sensitivity of ~1 ct/sec. The already identified sources represent unusual objects which were source candidates *before* UHURU was launched (E.M. Kellogg, private communication). One might argue, therefore, that more significant than the identifications with objects such as 3C273, NGC 1275 and NGC 4151 is the lack of observable emission from objects such as NGC 4051, i.e. the number of source identifications is not expected to scale anything like the number of observable sources at higher sensitivity.

Finally, the question of whether or not a local model can be excluded by the existing data is crucial. Matilsky, et al. argue that the UHURU data do, in fact, preclude a local model, and we shall devote the remainder of this paper to demonstrating otherwise. For energies > 2keV, observations through the galactic plane correspond to an optical depth of less than unity in any direction, as the ϵ=2keV absorption cross-section is $\sigma \sim 3 \times 10^{-23}$ cm^2 per H-atom (Brown and Gould 1970), and the columnar hydrogen density for various longitudes in the plane is in the range N= $(0.6-3) \times 10^{22}$ cm^{-2} (Daltabuit and Meyer 1972). For $\sigma N<1$ we can approximate the net 2-10 keV intensity observed in the plane with

$$I_{net}=I_{b=o}-I_{b=\pi/2}\approx N\left[\frac{jn_s}{4\pi n_H} - \int_2^{10keV} \sigma(\epsilon)\,\frac{dI_D}{d\epsilon}\,d\epsilon\right] cm^{-2} sec^{-1} sr^{-1}, \quad (1)$$

where $j \equiv$ mean source emissivity (2-10 keV photons/sec),

$n_s \equiv$ number density of discrete sources (cm^{-3}),

$n_H \equiv$ mean number density of interstellar hydrogen in the disk (cm^{-3}),

I_D = extragalactic diffuse sky background (cm^{-2} sec^{-1} sr^{-1}), and we assume that the distance to which discrete sources in the line of sight exist scales with N. In the absence of galactic emission in the 2-10keV range, equation (1) demonstrates that I_{net} should be less than zero, i.e. a lower intensity should be measured in the galactic plane than at $b=\pi/2$ owing to the absorption of the extragalactic component. For the UHURU 5°x5° detector, this deficiency should amount to ~2 cts/sec through ~10kpc of galactic hydrogen. Therefore, before considering the excess in the plane for I_{net} reported by Bleach, *et al.*, we can first observe the consequences of merely not observing a diminution of intensity in the plane, i.e. for $I_{net} \geq 0$, we require

$$j \geq \frac{4\pi n_H}{n_s} \int_2^{10\,keV} \sigma(\epsilon) \frac{dI_D}{d\epsilon} d\epsilon \qquad sec^{-1}. \tag{2}$$

If we take $n_H \approx 0.7\ cm^{-3}$, $\sigma(\epsilon) \approx (4x10^{21} \epsilon^3)^{-1}$ from Brown and Gould (1970), $dI_D/d\epsilon \approx 8\ \epsilon^{-1.4}$ from Boldt, *et al.* (1969) and $n_s = 2x10^{-6}\ pc^{-3}$ from Matilsky, *et al.*, we obtain $j \geq 7x10^{39}\ sec^{-1}$ corresponding to an average source luminosity in the energy band 2-10 keV of $L \gtrsim 5x10^{31}$ erg/sec. In other words, a plane excess of identically zero would demand local sources of luminosity detectable by UHURU as discrete objects at the Matilsky, *et al.* threshold of 3 sec^{-1} out to a distance of ~ 100 pc; this corresponds to $\lesssim$ 10 such detectable high latitude sources. The above calculation is relatively insensitive to the value of $dI_D/d\epsilon$ chosen from the literature (most others will be more favorable to our argument), and we have used the Matilsky, *et al.* value of n_s and their conversion factor (1 UHURU ct/sec $\doteq 1.7x10^{-11}$ ergs cm^{-2} sec^{-1}) in order that we insert a minimum of bias into this analysis.

Going one step further with the UHURU data alone, Matilsky, *et al.* place "an upper limit of 2 sec^{-1} in a typical galactic plane scan in the directions away from regions where stronger, low latitude sources are concentrated." Gursky (1972) has described significantly larger excesses in these latter regions which are due, at least in part, to "ordinary" $\geqslant 10^{36}$ erg/sec sources which are unresolved. If we again use the Matilsky, et al. n_s of 2×10^{-6} pc^{-3} and their "typical" upper limit of 2 sec^{-1} for a 5°x5° collimator we obtain $\lesssim$ 20 detectable sources with complete sky coverage at 3 UHURU cts/sec, so that a local source hypothesis can account for only ~ 1/4 of the unidentified high latitude sources if we assume that this "typical" direction is representative of the volume within a few hundred parsecs of the sun.

Considering now the results of Bleach, et al., I_{net} was directly measured to be 2.9 cm^{-2}sec^{-1}sr^{-1} in the direction of ℓ=60° (N= 2×10^{22} cm^{-2}), with a best-fit disk width of 2°. Based upon this result, we would expect UHURU to observe a ridge of ~ 6cts/sec in the direction of ℓ=60°. We note, however, that this is probably close to the maximum observable disk intensity (as a function of galactic longitude) from low luminosity sources, as we have assumed that I_{net} is directly proportional to N; near N=$.6 \times 10^{22}$ cm^{-2} for example, we would expect a ridge of only ~ 2 cts/sec in UHURU units. Undue significance should not be attached to the exact coincidence of this number with the UHURU "typical" upper limit, as parameters such as the scale height of the local source distribution can be adjusted significantly without violating agreement with the Matilsky, et al. or Bleach, et al. data; the important point is that the two are comparable. If we assume that the local source density n_s is representative of that in the direction of $\ell=60°$, it can be estimated directly from the measured Bleach, et al. integral source function of $\sim 7\times10^{-30}$ergs cm^{-3}sec^{-1}. The half-width of this source "disk" has a best-fit value of ~ 0.2 kpc, and with a threshold at 3 UHURU counts/sec roughly equivalent to this distance, complete sky coverage should yield ~ 30 discrete sources; roughly the same number should be obtained even if the source horizon is moved out somewhat beyond the source disk, in order to be commensurate with the slightly flattened log N-log S slope and low latitude source clustering. This is about a factor of two below the number required to reconcile the UHURU data; if we assume that ~1/3 of the 33 Matilsky, et al. sources are truly extragalactic on the basis of present associations, complete sky coverage will yield ~60 unidentified sources at a threshold of 3 UHURU cts/sec. Considering the uncertainty in the integral source function used (see Bleach, et al. for a detailed description of its estimation) and the small size of the Matilsky, et al. sample, we cannot exclude the possibility that local sources can account for most of the unidentified high latitude UHURU sources.

In summary, all of the data we are aware of is consistent with there being a population 10^{32-33}erg/sec 2-10keV sources with density $\sim10^{-6}$pc^{-3} and confined to within ~200pc of the plane. This population can account for most of the unidentified high latitude UHURU sources, obviating the necessity of the postulation of a new class of ultra-luminous extragalactic x-ray emitters. We suggest that the present model may be tested in the immediate future through the analysis of UHURU data which has already been accumulated. In particular, the lack of a region in the plane for which $I_{net} < 0$, and a marked (perhaps a factor of two) decrease in the observed source number from that expected after scaling in accordance with the present fractional sky coverage, would strongly favor a local source hypothesis for the majority of the unidentified high latitude sources.

REFERENCES

Bleach, R.D., Boldt, E.A., Holt, S.S., Schwartz, D.A., and Serlemitsos, P.J. 1972, Ap. J. (Letters), 174, L101

Boldt, E.A., Desai, V.D., Holt, S.S., and Serlemitsos, P.J. 1969, Nature, 224, 677

Brown, R., and Gould, R. 1970, Phys. Rev., D1, 2252

Giacconi, R., Murray, S., Gursky, H., Kellogg, E., Schreier, and Tananbaum, H. 1972, Ap.J., 178, 281

Giacconi, R., Murray, S., Tananbaum, H., Kellogg, E., and Gursky, H. 1971, Bull A.A.S., 3, 477

Gursky, H. 1972, Proceedings of the Summer School, Les Houches, (Gordon and Bleach, to be published)

Kellogg, E.M. 1972, Proceedings of the 55th Cospar Symposium, Madrid (to be published)

Matilsky, T., Gursky, H., Kellogg, E., Tananbaum, H., Murray, S., and Giacconi, R. 1973, Ap. J. (in press)